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**FISHERIES**

**SWFSC**

**Santa Cruz, CA**

# 4.0 Climate Change and Salmon Recovery Overview

*Nate Mantua*

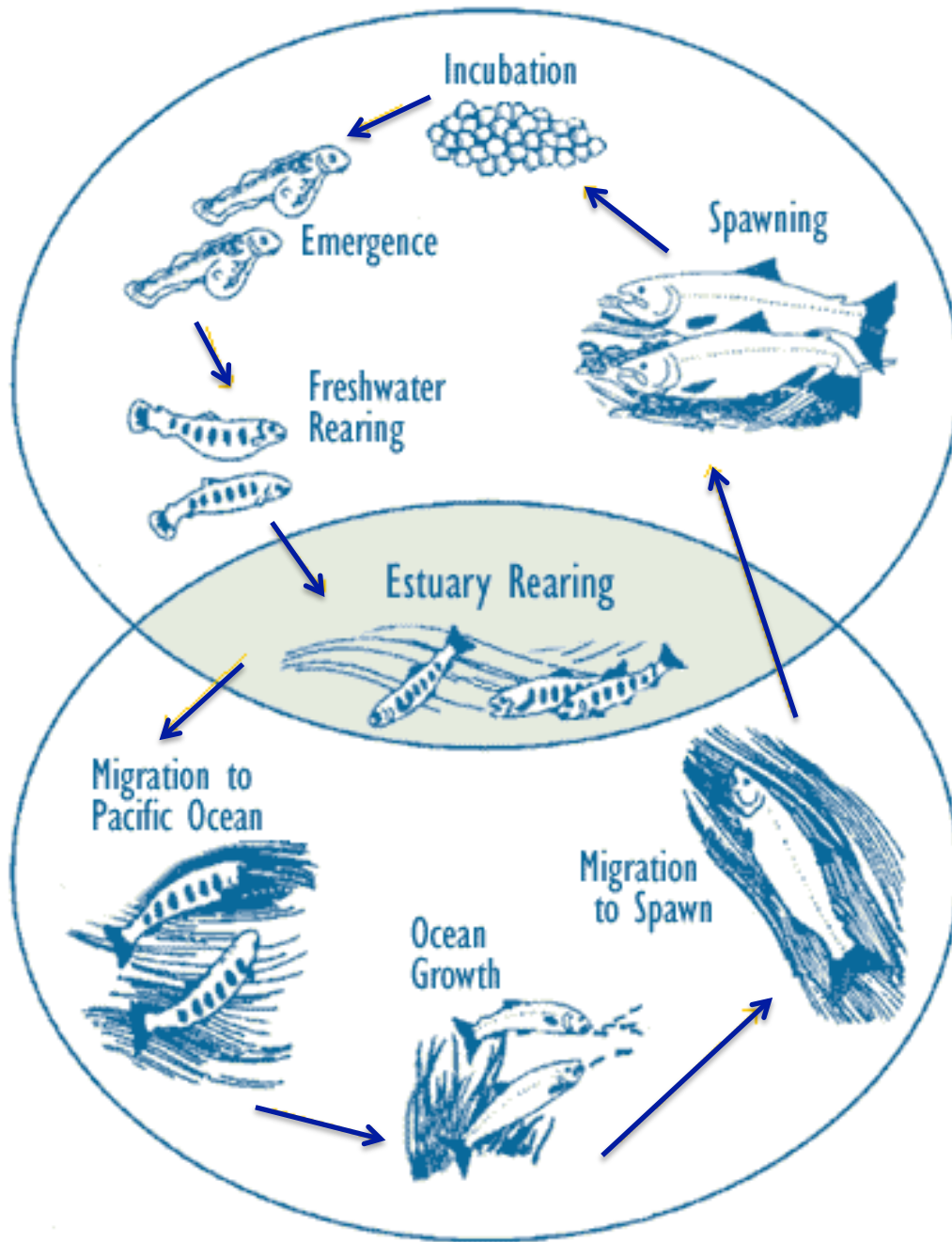
West Coast Protected Fish Species Program Review

Seattle, WA

May 4, 2015

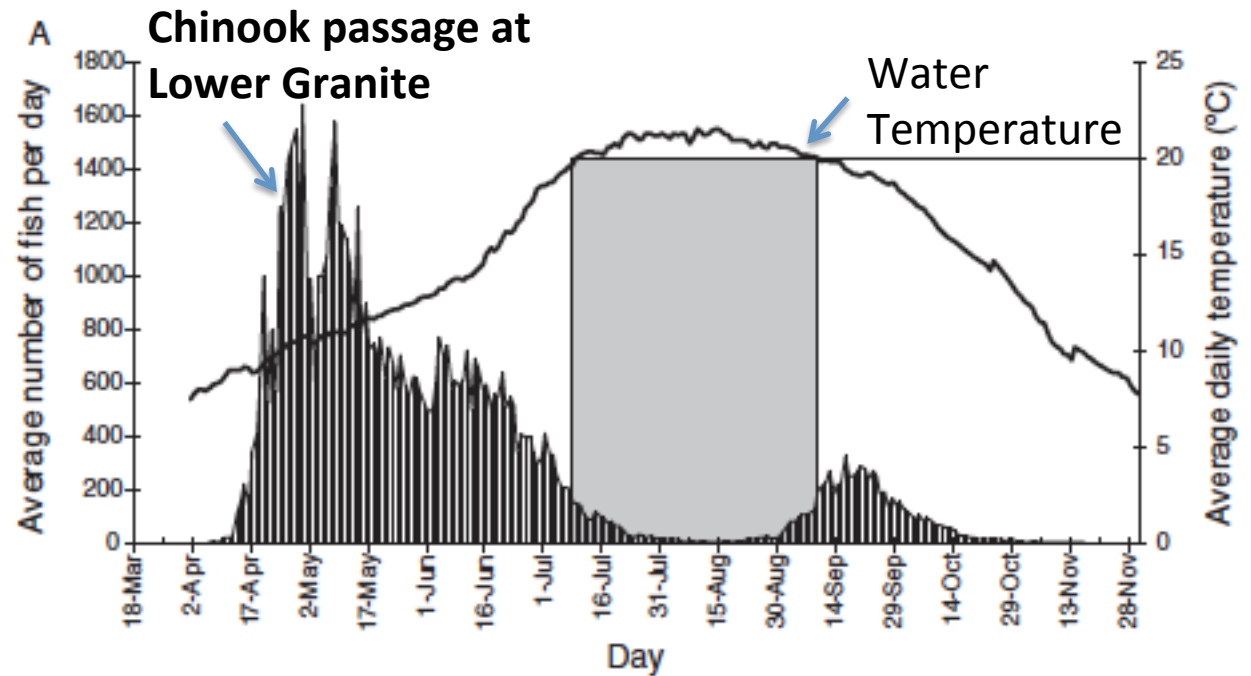
# Climate matters for salmon

- complex lifecycle requires a chain of different habitats to be favorable across space-time; sequential habitat needs set by different life history patterns
- flow and temperature are critical climate pressure points in freshwater habitats
- marine food-web is critical for ocean growth



# Adult salmon migration and water temperature

- For many West Coast salmon populations, adult spawning migrations are sensitive to water temperatures  $> \sim 20^{\circ}\text{C}$



Averages for 1995-2006

Crozier et al. 2008: Evolutionary responses to climate change in salmon. *Evolutionary Applications*, doi:10.1111/j.1752-4571.2008.00033.x

## Klamath River fish kill 2002 – a case where a short-term drought amplified management-related stresses on cold water

- Disease, high fish densities, low flows and a very warm river combined to result in a massive kill of adult chinook salmon in the lower Klamath River

High-temperature fish kills not unique to the Klamath in 2002

- near miss in 2014?
- 2013 Chinook kill in MF John Day
- 95% CV winter-run egg-to-fry mortality in 2014



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## Pacific Fishery Management Council ***NEWS RELEASE***

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FOR IMMEDIATE RELEASE

: Thursday, April 10, 2008

Contact: Ms. Jennifer Gilden, Communications Officer, 503-820-2280  
Dr. Donald McIsaac, Executive Director, 503-820-2280

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### **RECORD LOW SALMON FISHERIES ADOPTED**

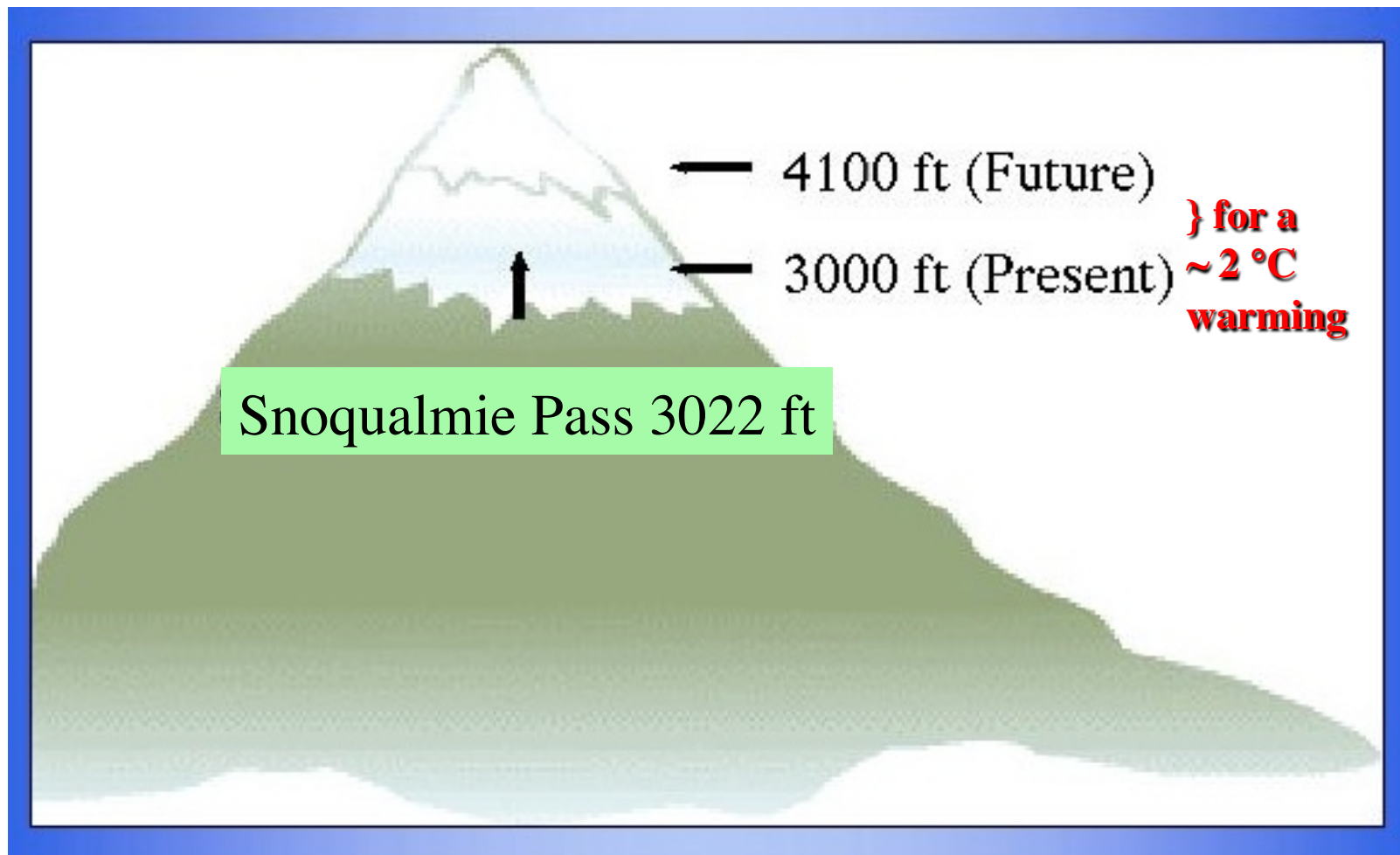
SEATTLE, Wash – The Pacific Fishery Management Council today adopted the most restrictive salmon fisheries in the history for the West Coast, in response to the unprecedented collapse of Sacramento River fall Chinook and the exceptionally poor status of coho salmon from Oregon and Washington. The recommendation will be forwarded to the National Marine Fisheries Service for approval by May 1, 2008.

"This is a disaster for West Coast salmon fisheries, under any standard," said Council chairman Don Hansen. "There will be a huge impact on the people who fish for a living, those who eat wild-caught king salmon, those who enjoy recreational fishing, and the businesses and coastal communities dependent on these fisheries."

- Climate extremes had a hand in this disaster too ... this time it was terrible ocean conditions due to delayed upwelling in 2005, and poor upwelling in 2006

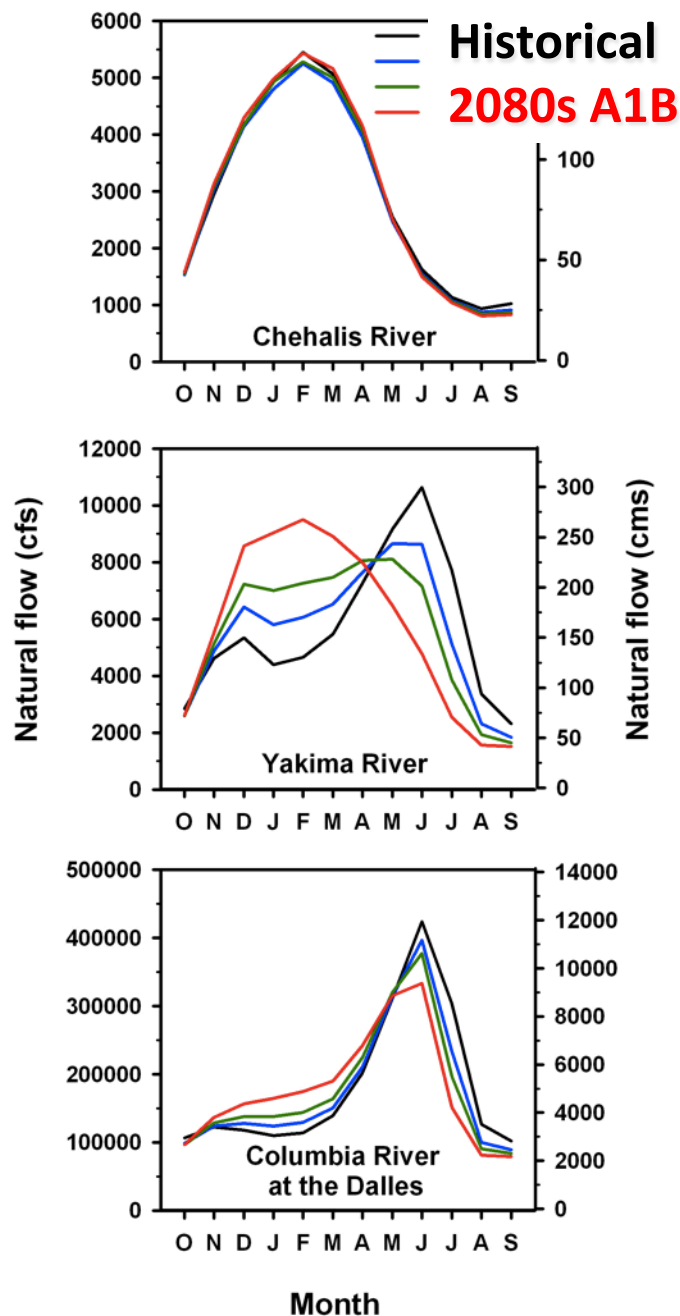


# A robust impact of climate warming for the west coast US: **less snow**

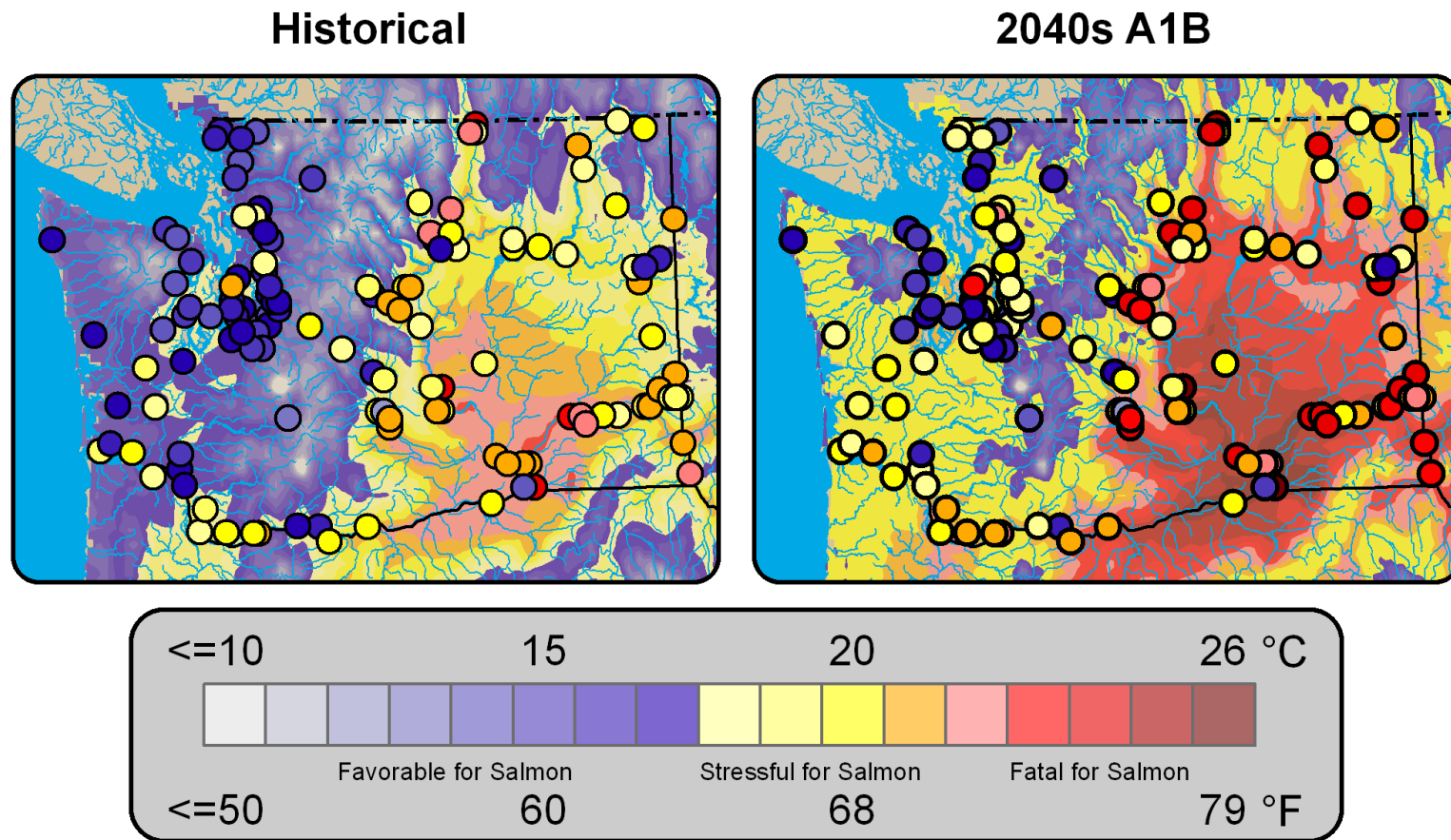


## 3 basic streamflow patterns

1. *rain-dominated*
2. “*transient*” runoff basins with an early winter peak from rainfall, and a spring peak from snowmelt
3. *snowmelt-runoff* basins, where streamflow peaks in late spring and early summer



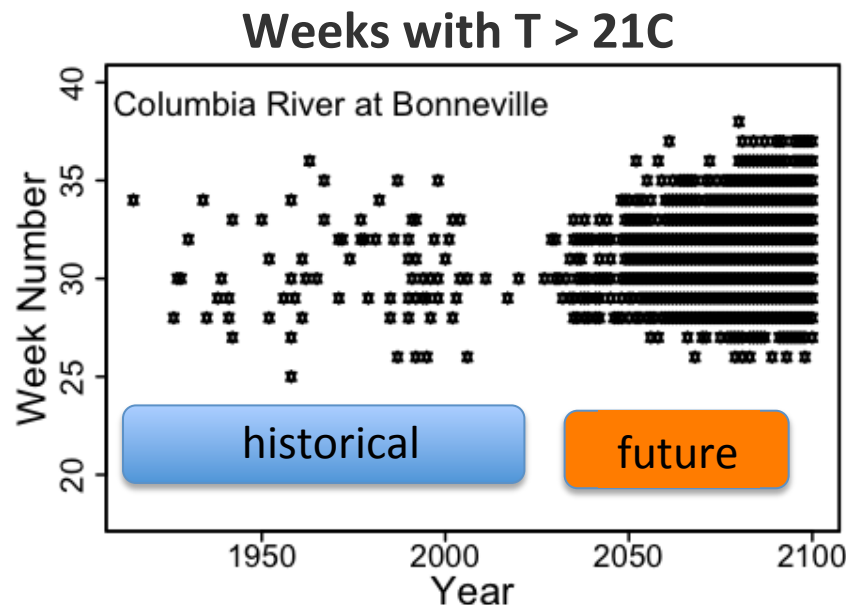
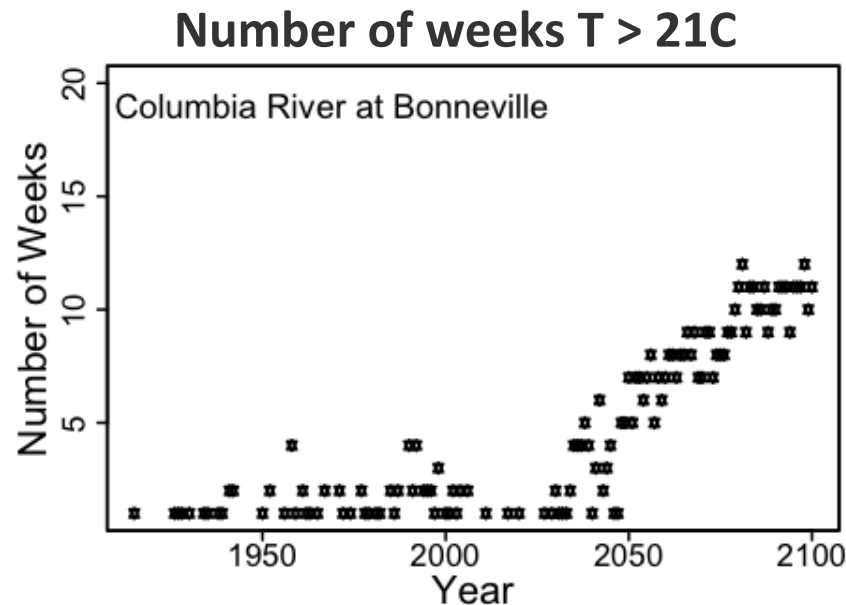
Western Washington's "maritime" summer climate becomes as warm as today's interior Columbia Basin, temperatures in the interior Columbia Basin become as warm as today's Central Valley in California



Mantua et al. 2010: Climatic Change



# Thermal stress season



- Use a simple regression model to translate future air temperature scenarios into stream temperature scenarios
- Extended periods with weekly average water temperatures  $> 21^{\circ}\text{C}$ 
  - the season of thermal migration barriers for migrating salmon predicted to last up to 12 weeks in the mainstem Columbia River

**Key climate change issues for salmon recovery:** changes in hydrology, temperatures, and ocean conditions are likely to compound existing stressors on salmon

$$\text{vulnerability} = (\text{sensitivity} \times \text{exposure}) / (\text{adaptive capacity})$$

- Reduced adaptive capacity due to diminished diversity, abundance, distribution, and productivity
- Sensitivity is especially high for populations using sub-optimal habitats
- Increased exposure due to the cumulative impacts of lost, simplified and degraded habitat due to land/water use actions and hydrologic impacts of a warming climate

### **Decision-support needs**

- Restoration partners and planners, including water managers, are lacking tools, information, and coordination needed for effective recovery actions (water management, habitat restoration, hatchery practices, etc.)
- Targeted science aimed at informing trade-offs over water resources and in related political decisions



# What we're doing: Science for Decision Support aimed at effective management actions, including restoration

## Research to support effective management and restoration actions

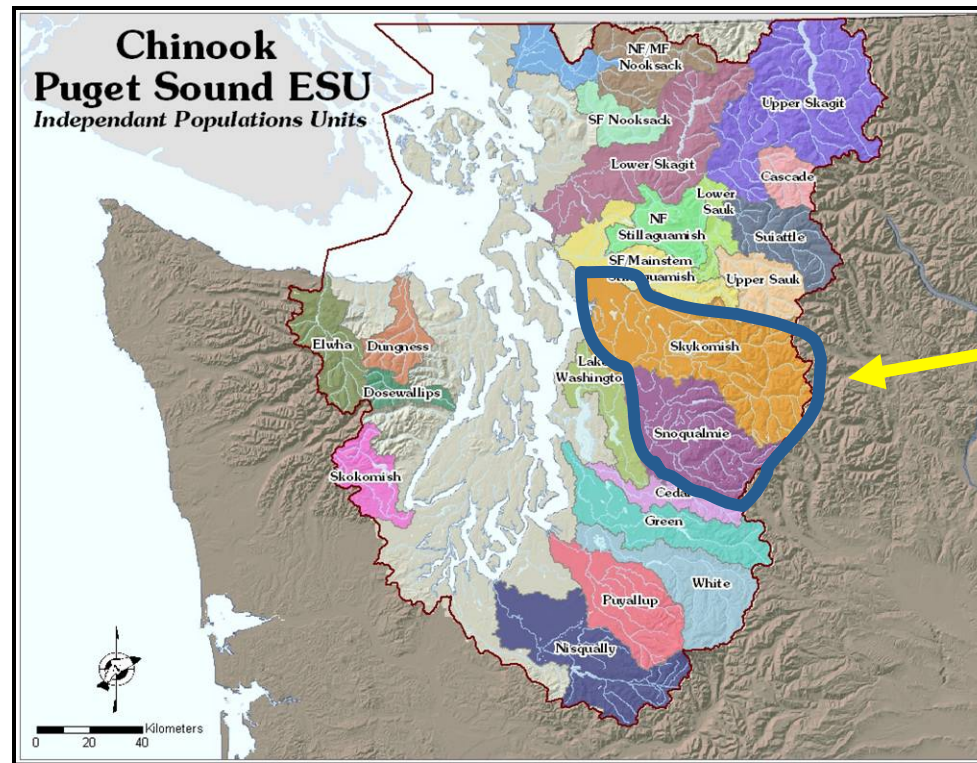
- Process-based habitat / physiology / life cycle modeling
- Evolution and plasticity studies through a climate change lens
- Extinction risk studies
- Evaluating impacts of restoration and climate change scenarios
- Developing decision-support tools

## Synthesis and Advice

- the recently developed West Coast Climate Team for coordinating climate science and its use in West Coast Regional office
- Supporting biological opinions and recovery plans
- Developing review papers and synthesis papers



# Snohomish Basin Case Study



Snohomish R.

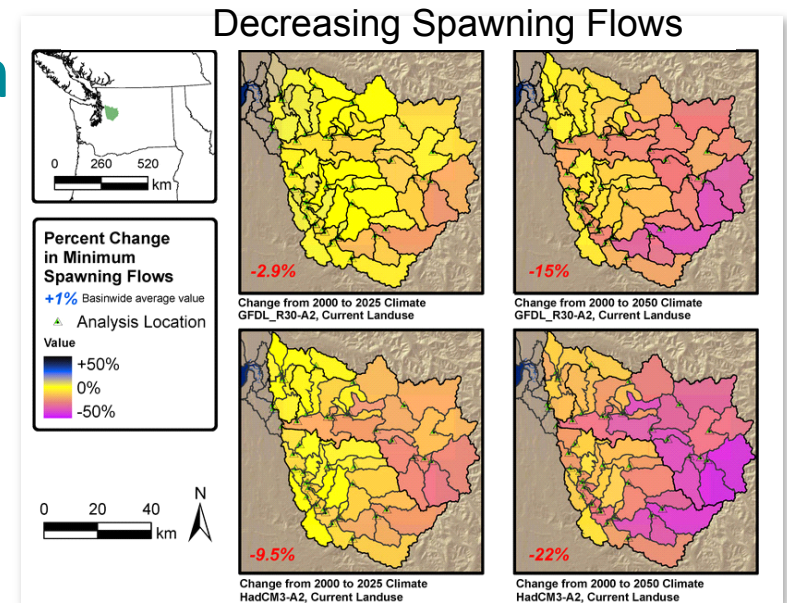
- Evaluate the benefits of alternative habitat restoration plans under different future climate scenarios using linked hydrologic and salmon-lifecycle models

Battin et al. 2007: PNAS



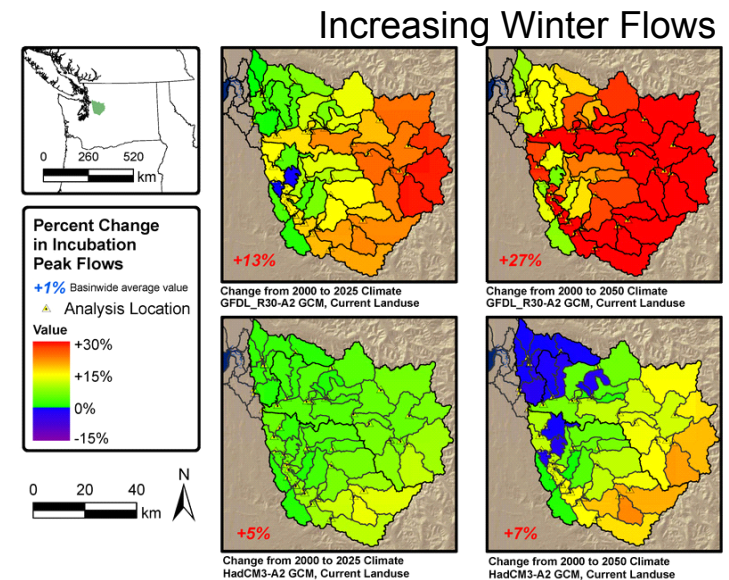
# Impacts of Climate Change on Salmon Recovery in the Snohomish River

(Battin et al. 2007: PNAS)



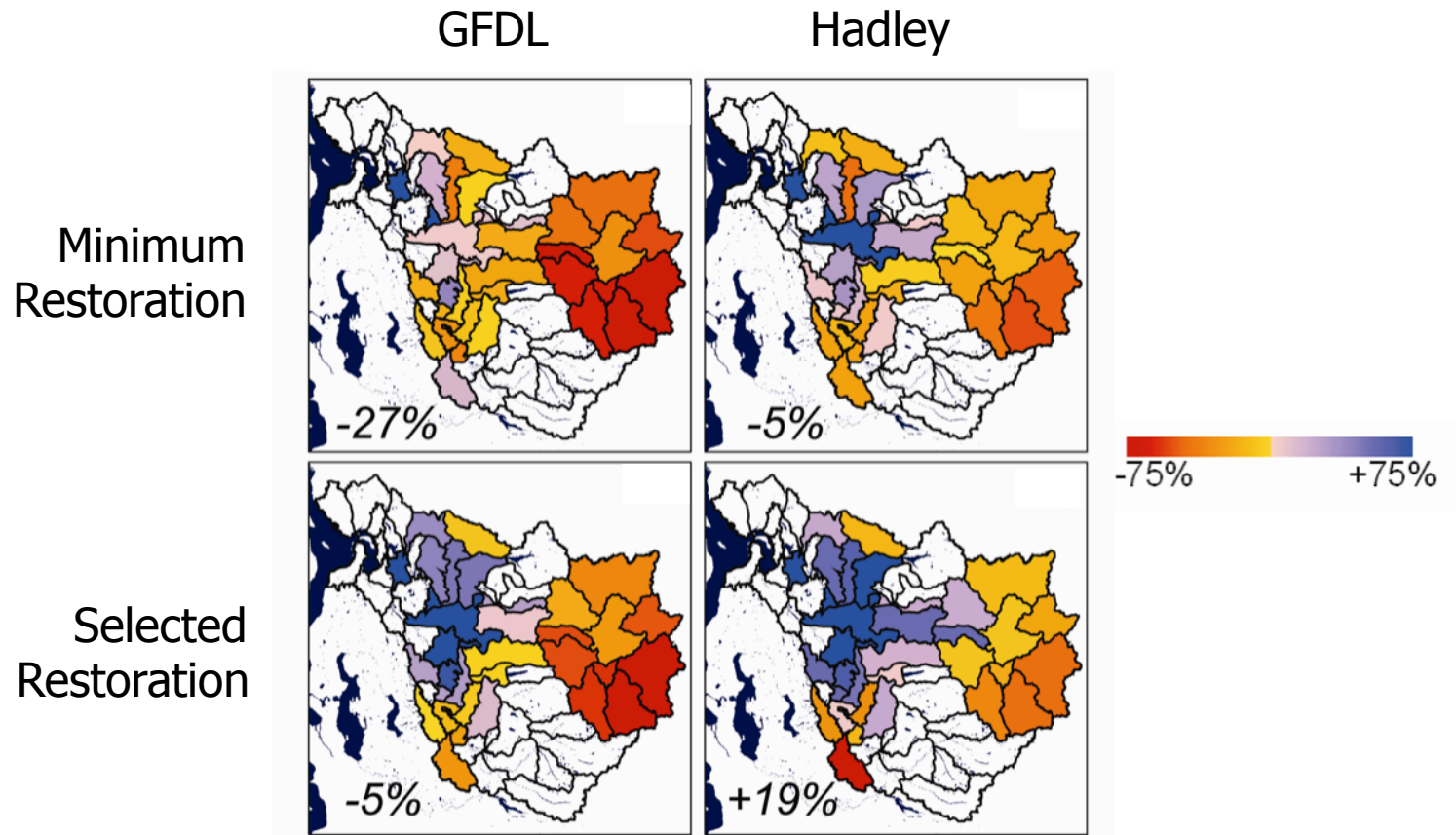
Climate Change will make salmon restoration more difficult:

- Decreasing Summer Low Flows
- Increasing Winter Peak Flows
- Increasing water temperatures in critical periods





# Predicted change in the distribution of wild spawners by 2050



- Negative effects of climate change are concentrated at higher elevations
- Positive effects of restoration are concentrated at lower elevations
- Effects are likely to increase the proportion of Chinook spawning at lower elevations

# Steelhead vulnerability to climate change in the Pacific Northwest

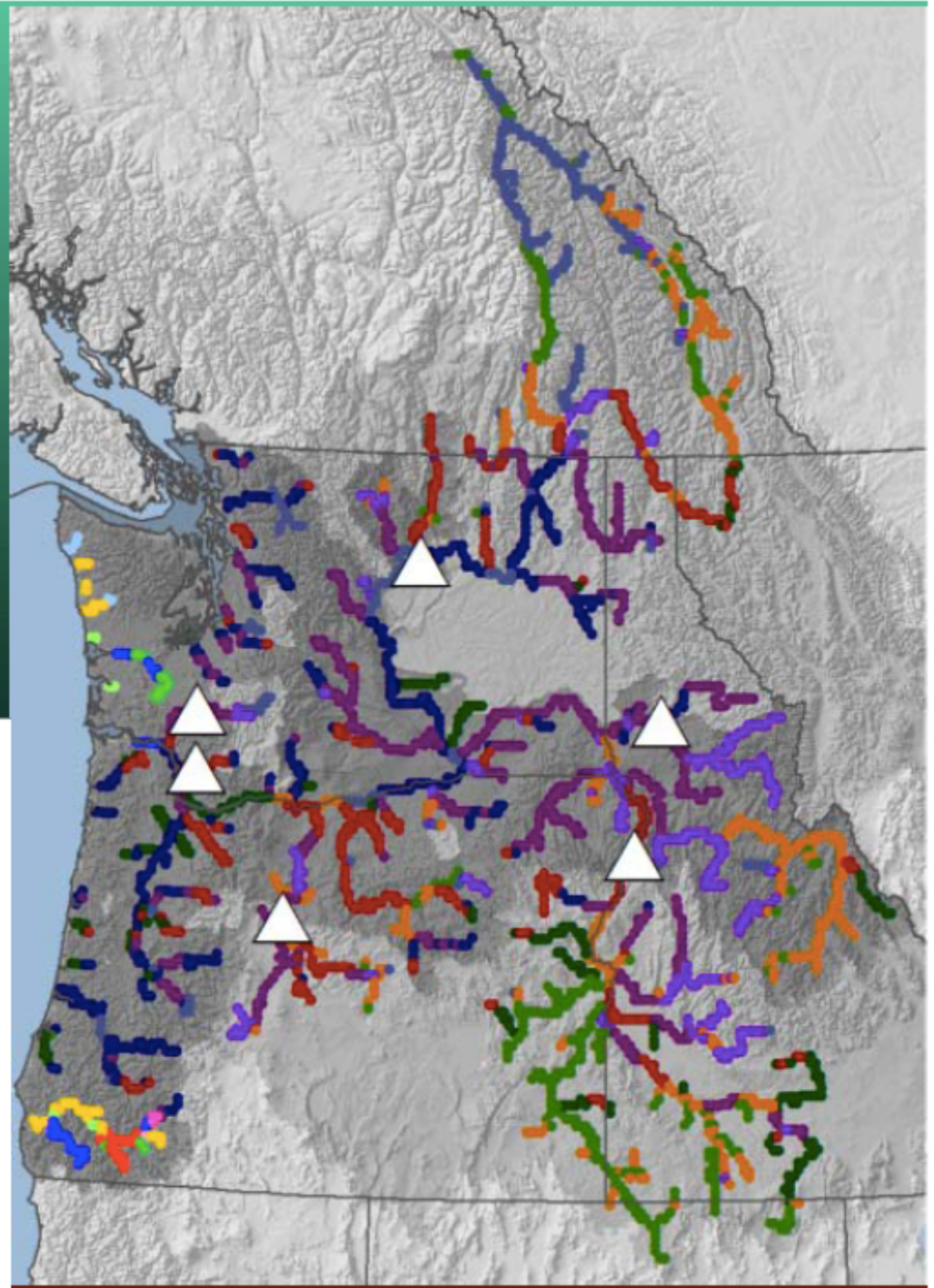
Alisa A. Wade<sup>1\*,†</sup>, Timothy J. Beechie<sup>2</sup>, Erica Fleishman<sup>3</sup>, Nathan J. Mantua<sup>4</sup>, Huan Wu<sup>5‡</sup>, John S. Kimball<sup>5</sup>, David M. Stoms<sup>6</sup> and Jack A. Stanford<sup>5</sup>

- “*Exposure*” informed by future stream flow and stream temperature scenarios
- “*sensitivity/adaptive capacity*” informed by habitat and stock condition (VSP parameters and NMFS status reviews)
- Allowed for a spatially and population specific assessment of key factors underlying vulnerability
  - For some cases, assessment highlights vulnerability related to increased spawning flows, or warming migration temperatures ... in others, key factor is poor habitat and/or stock status leading to very high sensitivity / low adaptive capacity

# PNW Steelhead Vulnerability

exposure x sensitivity  
(2080)

Stock Stress	L		H	
	Q Risk	H		
L	33	34	43	44
	31	32	41	42
H	13	14	23	24
	11	12	21	22
L		H		
T Risk		H		
Habitat Stress				



## RESTORING SALMON HABITAT FOR A CHANGING CLIMATE

T. BEECHIE<sup>a\*</sup>, H. IMAKI<sup>a</sup>, J. GREENE<sup>a</sup>, A. WADE<sup>b</sup>, H. WU<sup>c,d</sup>, G. PESS<sup>a</sup>, P. RONI<sup>a</sup>, J. KIMBALL<sup>e</sup>, J. STANFORD<sup>e</sup>,  
P. KIFFNEY<sup>a</sup> AND N. MANTUA<sup>f</sup>

River Research and Applications (2012)

How should habitat restoration plans be altered to accommodate climate change effects on stream flow and temperature?

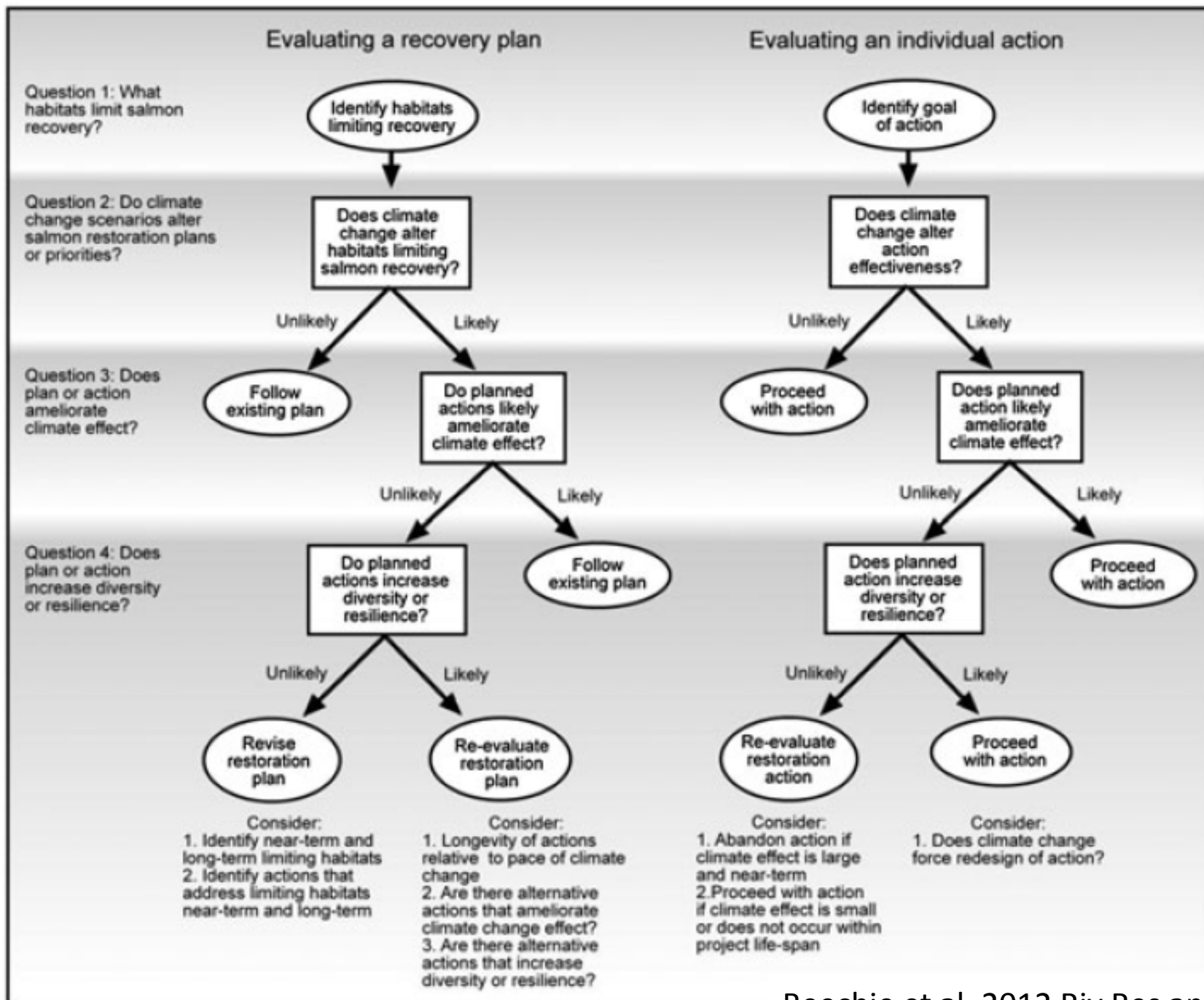
- We developed a decision-support process for adapting recovery plans that incorporates (1) local habitat factors limiting salmon recovery, (2) scenarios of climate change impacts on flow and temperature, (3) the ability of restoration actions to ameliorate climate change effects, and (4) the ability of restoration actions to increase habitat diversity and salmon population resilience

# Restoration actions and their ability to ameliorate climate impacts

Category	Common techniques	Ameliorates temperature increase	Ameliorates base flow decrease	Ameliorates peak flow increase	Increases salmon resilience
Longitudinal connectivity (barrier removal)	Removal or breaching of dam	●	●	○	●
	Barrier or culvert replacement/removal	○	○	○	●
Lateral connectivity (floodplain reconnection)	Levee removal	●	○	●	●
	Reconnection of floodplain features (e.g. channels, ponds)	●	○	●	●
	Creation of new floodplain habitats	●	○	●	●
Vertical connectivity (incised channel restoration)	Reintroduce beaver (dams increase sediment storage)	●	●	●	●
	Remove cattle (restored vegetation stores sediment)	●	●	●	○
	Install grade controls	●	●	●	○
Stream flow regimes	Restoration of natural flood regime	●	●	○	◐
	Reduce water withdrawals, restore summer baseflow	●	●	○	○
	Reduce upland grazing	○	◐	◐	○
	Disconnect road drainage from streams	○	○	●	○
	Natural drainage systems, retention ponds, other urban stormwater techniques	○	◐	●	○

Beechie et al. 2012: Riv. Res. and Appl.





# Conservation Biology Special Issue on Climate Change and the ESA

## Synthesis and Advice

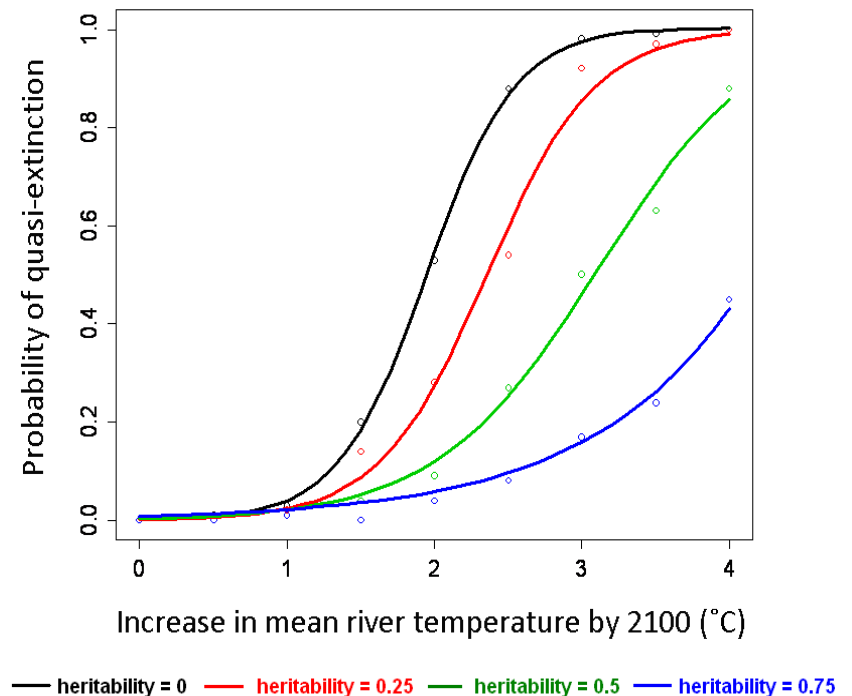
- Incorporating Climate Science in Applications of the U.S. Endangered Species Act for Aquatic Species (McClure et al. 2013)
- Choosing and Using Future Climate Change Scenarios for Impacts Assessment (Snover et al. 2013)

## Research

- Impacts of water diversion and climate change on Chinook Salmon in the Lemhi Basin (Walters et al. 2013)
- Floodplain Rehabilitation as a Hedge against Hydroclimatic Uncertainty in a Migration Corridor of Threatened Steelhead (Boughton and Pike 2013)

# Research themes: evolution and plasticity

- Workshops and symposia: Seattle 2006, Vancouver 2012
- IBM for evaluating role of heritability in upstream migration timing in extinction risk under varying temperature scenarios (Reed et al 2011)
- Empirical studies: evolutionary and plastic responses to environmental change: case study of Columbia Basin sockeye return timing (Crozier et al. 2011)
- Synthesis/review papers, comment letter (Crozier et al. 2008, Crozier and Hutchings 2014, Mantua et al 2015)



Effects of evolution on quasi-extinction risk for a modeled population of sockeye salmon that experience warming temperatures in the Fraser River (Reed et al. 2011)



# Synthesis and Advice: West Coast Region Climate Team

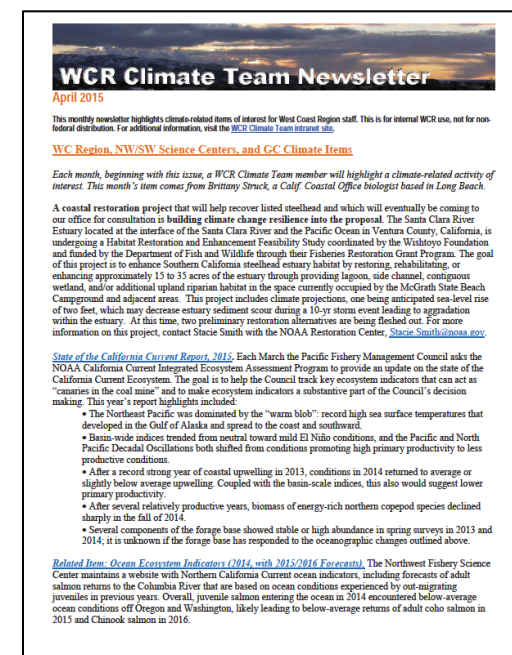
Composed of Regional Office, Science Center, General Counsel, and Restoration Center representatives

## Purposes:

- Promote consistent treatment of climate change in WCR analyses and decisions.
- Provide access to climate change information, training opportunities and tools, for all staff.
- Coordinate WCR responses to NOAA and NMFS HQ requests.
- Coordinate WCR interactions with other agencies and groups involved in climate change research and management activities.

## Some Team Activities:

- Monthly meetings among Science Centers, WCR divisions, external guests, etc.
- Monthly newsletter with new information and resources for staff
- Developing guidance to address climate change in ESA consultations (biological opinions)
- Incorporating climate change considerations into revised fish passage guidelines
- Regional representation and coordination on HQ projects:
  - e.g., NMFS Climate/ESA policy; NMFS Climate Science Strategy; NMFS Climate Vulnerability Analyses; Sustaining Marine Ecosystems in a Changing Climate



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# Climate Change in salmon recovery plans

**Very little or no Climate Change Info (2005-2009):** Lake Ozette sockeye, Puget Sound Chinook; Upper Columbia Steelhead; Upper Columbia Chinook.

**Some Climate Info, Could Use Updating (2009):** Middle Columbia R. steelhead.

**Substantial Info Provided (2013-2014):** Columbia River chum; Lower Col. R. Chinook; Lower Col R. steelhead; Lower Col R. coho; South-Central CA Coast steelhead; S. CA steelhead; CC coho; Sacramento Winter-run Chinook; Central Valley Spring-run Chinook; Central Valley steelhead; Central CA coast coho; SONCC coho.

**In Development:** CA Coastal Chinook; C.CA Coast steelhead; N. CA Coast steelhead; Oregon Coast coho; Snake River sockeye, Snake River steelhead; Snake River spring/summer Chinook; Snake River fall Chinook.





# What we could be doing for Climate Change and Salmon Recovery

- Climate change vulnerability assessments for salmon populations in specific watersheds, ESUs and/or regions (like Wade et al.)
  - Also need quantitative viability assessments
- Identifying climate change refugia for specific watersheds, ESUs and/or regions
  - we are currently developing, testing, and using methods for quantifying spawning and rearing habitat capacities in currently inaccessible habitats (behind high dams) on the upper Merced and Tuolumne Rivers
  - landscape-scale evaluation of cold-water refugia with FLIR data
- Climate change and salmon predator studies
- More work on climate change and salmon ocean ecology



# Future Challenges and Opportunities

Maintaining momentum after the crisis of the day passes

- Current CA drought has led to new funding, more hires, and more research activity. Can we maintain this momentum going forward?

Making progress on ocean ecology and climate change

- hampered by the lack of key pieces that include: understanding more details of salmon ocean ecology, complexity of marine food webs, a lack of published work on future ocean conditions (physical, chemical, biological, and food webs)

Continued coordination within NOAA line offices on ocean conditions

- NOAA's OAR and NMFS work on climate change and seasonal forecasting for west coast ocean conditions

